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STUDY OF THIN FILM LARGE AREA PHOTOVOLTAIC SOLAR ENERGY CONVERTER

Monthly Status Report
July 1 through July 31, 1964

Contract NAS3-2795

National Aeronautics and Space Administration
Lewis Research Center

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1. PRODUCTION OF EVAPORATED FILMS

Twenty-eight evaporations (Nos. 206T through 233H) were completed in July. The yield was one 4 inch x 4 inch CdS film on Textolite, thirty-two 1 inch x 2 inch films on glass, and twenty-three evaporations on H-Film substrates. Of these, twenty were 3 x 3 arrays totaling 180 individual 1 $inch^2$ cells and three were 4 inch x 4 inch single cells.

2. PROCESSING PHOTOVOLTAIC CELLS

Cadmium sulfide film arrays frequently separate from embossed H-Film substrates on flexing. This is due to the small radii of curvature encountered at the periphery of each hemispherical cavity. The situation is aggravated when these embossed films are laminated because this process causes dimpling of each of the cavities, increasing the number of ridges representing small radii of curvature.

On the other hand, recent improvements in lamination techniques permit the fabrication of quite flat cell arrays on unembossed H-Film. For this reason, therefore, most of the effort is being turned to making cells on unembossed H-Film. Adherence of CdS to unembossed H-Film is adequate for processing without acid etching. Subsequent lamination essentially removes the danger of separation of the CdS from the H-Film.

Finished cells on unembossed H-Film have been laminated into single cells, series connected combinations and series-parallel connected combinations. Initial experiments with various lamination procedures yielded cells with efficiencies reduced by approximately 40 percent. This was manifested by a reduction in Fill Factor or increase in series resistance. It was thought that lamination introduced stresses tending to increase the contact resistance between the electrodes and barrier layer or n-type CdS. Evidence has been obtained showing that this defect will be overcome as lamination techniques continue to improve.

The barrier collector electrode for all cells is Waldman's #3030 silver past diluted with acetone. Other diluents were found to be less suitable and toluene to be actually harmful (perhaps as a result of contamination of the toluene). The adherence of the Waldman paste is less than desirable. Some epoxy silvers with desirable adherence were not electrically suitable. Additional silver preparations with desirable mechanical and electrical properties are being sought.

The electroplated nickel n-type electrode, while easily applied to glass cells, is not presently applicable to the H-Film array because rather complicated masks would be required. An evaporated gold n-type electrode is being employed for cells on H-Film.

The best glass cell efficiency remains somewhat in excess of 3 percent; Cell No. 228-5, fabricated with the slurry, has an efficiency of 3.4 percent; Cell No. 174-6, fabricated with the cuprous chloride dip also has an efficiency of 3.4 percent. The major problem areas are still current collection and reduction of series resistance.

Cells fabricated in July are listed in Table 1. Unexpectedly large short circuit currents were observed in cells 217-2 and 217-4. These large currents are undoubtedly associated with the fact that the electrodes were still wet when the measurements were made and may perhaps be due to some sort of galvanic cell action. On the other hand, there may be much less contact resistance in the wet state than is present when the electrodes are dry. In any case, this phenomenon should be investigated further.

3. H-FILM SUBSTRATE CURLING PROBLEM

The curling problem occupied nearly all of the project effort during July. At first, emphasis was placed on embossed films, but, as mentioned above, attention was later transferred to laminated films because of the adhesion problem with the embossed films. Experiments using a wire screen optical filter as the embossing die were described in the Third Quarterly Report and were continued in July until the jig for hold steel bearing balls was completed. Most of the experiments in July were done with this jig. Three ball diameters were employed, 1/16", 3/32", and 1/8". Of these, the 3/32" diameter balls produced the best compromise between flattest and thinnest embossed films. The embossing was done at a temperature of 260°C and a force of 16000 pounds (1000 psi). After

TABLE 1

CdS Thin Film Photovoltaic Cells Fabricated in July, 1964

Date	Cell Number	V_{oc}, Volts	j_{sc}, $mA\text{-}cm^{-2}$	Cell Area, cm^2	Eff., %	Process CuCl Dip or Slurry	
7/ 2	187-3	0.31	14.3	5.6	1.7	Dip	N.S.*
7/ 2	181-8	0.36	14.3	8.4	2.1	Dip	N.S.
7/ 6	208-H	0.38	10.7	2.4	1.9	Slurry	
7/ 7	114-6	0.37	18.8	7.3	3.4	Dip	
7/ 7	189-2	0.36	16.4	7.7	2.6	Dip	
7/ 8	156-5	0.36	15.0	6.9	3.2	Dip	
7/ 8	187-4	0.37	15.0	7.5	2.9	Dip	
7/10	212-H	0.28	----	----	---	Dip	N.G**
7/10	159-7	0.31	14.5	6.9	1.5	Dip	
7/13	185-2	0.31	----	7.7	1.5	Dip	
7/14	187-1	----	----	----	----	-	N.G.
7/14	186-6	0.33	12.5	7.5	1.8	Dip	
7/15	191H-A	High series resistance				Slurry	
7/15	110-5	Film separated from substrate					
7/16	184-3	----	----	---	---	-	N.S., N.G.
7/16	190-1	0.41	15.0	7.7	2.3	Dip	
7/16	217-3	0.34	13.0	7.1	1.8	Dip	
7/16	217-5	0.38	17.1	7.8	3.3	Slurry	
7/17	217-6	0.39	14.1	8.0	2.8	Slurry	N.S.
7/20	217-2***	0.38	71.5	6.0	7.3	Slurry	Wet electrode
7/21	217-4***	0.37	31.6	7.6	3.2	Slurry	Wet electrode
7/22	173-8****	0.35	14.4	7.3	2.7	Slurry	
7/22	221H	Film separated from substrate					N.G.
7/27	183H	Set aside for lamination					
7/27	222H	High series resistance					
7/27	183H-A	Set aside for lamination					
7/28	226-1	High series resistance				Slurry	
7/28	226-4	High series resistance				Slurry	
7/28	183H-D,G	Set aside for lamination					
7/28	183H	Set aside for lamination					
7/28	227-5	0.39	16.7	7.6	3.2	Slurry	
7/29	226-2	0.37	7.8	8.1	1.3	Slurry	
7/29	228-5	0.40	19.1	7.7	3.4	Slurry	
7/30	229H	High series resistance					
7/30	223H	Film separated from substrate					
7/31	230H-E	0.20	8.7	2.6	0.9	Slurry	

* N.S. = Non-standard Process
** N.G. = No Good
*** Wet, One component epoxy silver. Deteriorated on heating.
**** Two component epoxy silver

encapsulation with mylar, the package was still flat but the hemispherical cavities were dimpled and this usually resulted in separation of the CdS layer from the H-Film substrate.

Toward the end of July it was observed that unembossed film cells could be laminated to mylar using capron as bonding agent. A package was made consisting of a sheet of 0.002 inch thick H-Film, a 3 x 3 array of 1 in^2 CdS cells, a 0.00075 inch thick sheet of capron and a 0.002 inch thick sheet of mylar. This multiple sandwich was pressed at 220°C for 4 minutes under a pressure of 100 psi. The resulting package was slightly bowed, the center rising about one inch above a flat table top, but could easily be flattened by pressing on the center with one finger. It is expected that further experimentation will result in an almost completely flat, flexible, package. An important point to be noted is that the encapsulation is on one side only. There is no plastic layer other than H-Film between the CdS cells and the source of radiation.

4. WORK PLANNED FOR NEXT MONTH

The work on laminating flat cells will continue with the expectation that cells with usable outputs will be obtained. Evaporations are on a scheduled basis aimed at producing the cells necessary for delivery to NASA. This will continue.

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